SAR Evaluation Considerations for Handsets with Multiple Transmitters and Antennas

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1. Introduction

This document describes the SAR evaluation considerations for cell phones with multiple transmitters and simultaneous transmitting antennas.[1] The procedures are applicable to phones with built-in unlicensed transmitters, such as 802.11 a/b/g and Bluetooth devices. The operating and exposure characteristics for these transmitters are examined in both stand-alone and simultaneous transmission conditions to streamline test requirements. Depending on output power, antenna configuration and SAR distribution, the number and types of tests necessary to show compliance for simultaneous transmission may vary with exposure potential. If the stand-alone 1-g SAR for each antenna is low, or the sum of the 1-g SAR for all transmitters is well within the SAR limit where overlapping SAR distributions are limited, SAR evaluation for simultaneous transmission may be unnecessary. When SAR evaluation for simultaneous transmission is not required, phones may be approved by a TCB according to procedures in this document. Otherwise, SAR results for simultaneous transmission and detailed descriptions of the volume scan and measurement procedures should be included in the SAR reports for equipment certification according to existing approval policies.[2]

2. SAR Evaluation Considerations

SAR test configurations are becoming more complex as products and technologies continue to evolve. The simple procedures applied to single transmitters are no longer sufficient for today's products with multiple transmitters and simultaneous transmitting antennas. For test reduction and exclusion, these exposure conditions can become quite complicated and are often unclear. Nevertheless, RF exposure concerns must still be addressed to ensure conservative and acceptable criteria are applied to establish the necessary procedures. For most conditions, parameters such as frequency, power and antenna and peak SAR separation distances can be considered to estimate near-field exposure potentials, to reduce the number of redundant and unnecessary tests for certain cell phone configurations. The procedures in this document are intended to simplify the tests required for phones with multiple transmitters and simultaneous transmitting antennas. Manufacturers can determine the conditions necessary to minimize or avoid these complex tests while products are being developed.

Existing SAR measurement standards are based on earlier generation handsets such as AMPS, GSM or CDMA (IS-95). These procedures are not fully adequate for evaluating the operating characteristics and exposure configurations of current generation cell phones. It can be difficult to assess test results and determine compliance if these single transmitter concepts are applied inappropriately to multiple antennas and different exposure conditions. Although many of the fundamental SAR measurement issues have been examined in on-going draft standards, the committees are just beginning to investigate the test and measurement issues associated with current generation products and technologies.

The random noise-like signals used in today's technologies have introduced new SAR measurement and probe calibration difficulties.[3] For devices operating in the 5 GHz bands, such as 802.11a, 3 – 6 GHz SAR measurement procedures are necessary.[4] Although transmit antenna diversity is quite common for 802.11 devices, SAR test procedures are still unavailable in any of the draft standards. Other forms of antenna diversity, such as MIMO and beam-forming, are already implemented in recent 802.11 products that also need test considerations. These 802.11 transmitters must be measured according to chipset test software, antenna diversity schemes and proprietary operating modes described in the 802.11 SAR

[1] This document applies to consumer cell phones authorized under Part 22H, 24E, 27L (AWS), and 90 SMR.

[2] Consult latest policies to determine if TCBs may approval devices that require SAR evaluation for simultaneous transmission.

[3] See http://www.fcc.gov/oet/ea/eameasurements.html#sar - KDB Publications 941225 and 450824.

[4] See http://www.fcc.gov/oet/ea/eameasurements.html#sar - KDB Publication 865664.

procedures.[5] In addition, the SAR measurement methods currently proposed in draft standards for simultaneous transmission are time consuming and inefficient because of fundamental constraints associated with volume scan measurements[6]. While there is an increasing need to simplify the test requirements, an acceptable level of conservativeness is also necessary to accommodate many of these measurement difficulties that remain to be resolved, to ensure compliance is not compromised. Since it could take some time to investigate and resolve the technical issues in standards settings, interim procedures are necessary to identify the tests required to show compliance for products that are already available on the market.

3. Individual Transmitters

Regardless of simultaneous transmission requirements, each transmitter operating in a cell phone must be assessed independently according to applicable rules and policies to determine RF exposure compliance. Routine SAR evaluation with respect to Section 2.1093 of the rules is required for licensed transmitters to show compliance; however, other policies and measurement requirements may apply to unlicensed devices. Since 802.11a transmitters can be authorized according to Sections 15.247 and 15.407 (UNII), the same RF exposure test procedures should apply to the same transmitter that qualifies under both radio services. Although routine SAR evaluation is required for Section 15.407 devices, the test exclusion and reduction procedures described in this document for unlicensed transmitters can be applied to 802.11a transmitters authorized under either Section 15.247 or Section 15.407, in conjunction with the SAR test procedures for 802.11 a/b/g transmitters in KDB 248227.[5]

For an unlicensed transmitter that does not transmit simultaneously with other transmitters and its output is $\leq 60/f_{(GHz)}$ mW, 1-g SAR evaluation is not required.[7] When simultaneous transmission applies, power thresholds (P_{Ref}) derived from multiples of $½\cdot 60/f_{(GHz)}$ are used to reduce stand-alone SAR requirements for unlicensed devices incorporated in cell phones. Values of P_{Ref} for applicable frequencies are shown in Table 1.[8] P_{Ref} is defined as the maximum conducted power available at the antenna according to source-based time-averaging requirements of Section 2.1093(d)(5). When the output of an unlicensed transmitter is $\leq P_{Ref}$ and its antenna(s) is $\geq$ 2.5 cm from other antennas, stand-alone SAR evaluation is not required for that unlicensed transmitter. When the output of an unlicensed transmitter is $\leq 2\cdot P_{Ref}$ and its antenna(s) is $\geq$ 5.0 cm from other antennas, stand-alone SAR evaluation is also not required for that unlicensed transmitter. Antenna separation is determined by the closest distance between the antennas. To facilitate streamlining simultaneous transmission test requirements for certain configurations with small antenna separations, it may be necessary to conduct stand-alone SAR evaluation at $\leq 2\cdot P_{Ref}$ (equivalent to $60/f_{(GHz)}$ mW). However, stand-alone SAR is not required for an unlicensed transmitter with output power $\leq P_{Ref}$ mW when either the output power or 1-g SAR for each of the other antennas within 2.5 cm of that unlicensed transmitting antenna is $\leq P_{Ref}$ mW or < 1.2 W/kg.

When SAR evaluation is required for an unlicensed transmitter, the following procedures apply. Among the channels required for normal testing, SAR must be measured on the highest output channel in all wireless modes and exposure conditions applicable to that unlicensed transmitter.[9] If the SAR measured on the highest output channel is < 50% of the SAR limit, SAR evaluation for the other required channels

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[5] See http://www.fcc.gov/oet/ea/eameasurements.html#sar - KDB Publication 248227.

[6] It has been reported that volume scans could be difficult for transmitters with substantially different operating frequencies due to incompatible measurement resolution and other SAR measurement system constraints. Contact the FCC Laboratory for possible interim solutions.

[7] This is a continuation of existing TCB approval policies.

[8] The procedures only apply to frequencies specified in Table 1.

[9] This is consistent with the existing 802.11 SAR procedures in KDB Publication 248227.

is unnecessary.[10] Otherwise, all required configurations must be tested according to the normal procedures required for that transmitter.

4. Simultaneous Transmission

Localized exposure limits adopted by the FCC require SAR compliance for any 1-g of tissue in the shape of a cube. The SAR distributions of transmitters and antennas in cell phones that contribute significantly to the 1-g SAR are typically of limited extent. However, at higher outputs the significance of overlapping SAR contributions is expected to vary with both power and antenna and peak SAR separations, where higher 1-g SAR may not be easily ruled out, especially if secondary peaks are embedded in the overlapping distributions. For certain clam-shell style phones that allow simultaneous transmission in body-worn accessories with the phone in its folded or closed position, the antennas can be very close to each other and the simultaneous transmission exposure conditions for head and body exposure configurations must be assessed independently to determine SAR evaluation requirements. When the peak SAR locations are closer than 5 cm from each other, certain higher output configurations may require simultaneous transmission evaluation to assess overlapping contributions for SAR compliance. The tests required for simultaneous transmission can be determined by the output power, antenna configurations and SAR distributions of each phone. Except for transmissions during network hand-offs, with maximum hand-off duration less than 30 seconds, transmitters are considered to be transmitting simultaneously when there is overlapping transmission. The SAR tests required for both head and body exposure conditions for simultaneous transmission must be clearly identified in the SAR report.

When stand-alone SAR evaluation is not required and the antenna is ≥ 5 cm from other antennas, simultaneous transmission SAR evaluation is also not required for that antenna.[11] Therefore, it does not need to be included in the simultaneous transmission evaluation of other antennas that require it. Furthermore, when simultaneous transmission applies and the sum of the 1-g SAR measured for all simultaneous transmitting antennas is less than the SAR limit, SAR evaluation for simultaneous transmission is not required for all transmitters and antennas.[12] Otherwise, the following procedures should be used to determine if SAR evaluation for simultaneous transmission is necessary. It should be noted that the term antenna(s) generally includes both intentional radiating antennas and other unintentional radiating structures that have significant contributions to the RF exposure evaluation. Radiating structures showing SAR higher than 25% of the SAR limit or higher than the maximum peak SAR in an area scan should be included in the determination of closest antenna separation distances.

Simultaneous Transmission SAR Test Procedures:

Based on the 1-g SAR limit of 1.6 W/kg and a 5 cm separation between peak SAR locations, a ratio of SAR to peak location separation is established to minimize SAR distribution overlaps. The need to evaluate SAR for simultaneous transmission is determined by examining the 1-g SAR of antennas one pair at a time. When the SAR to peak location separation ratio for a pair of antennas is < 0.3, SAR evaluation for simultaneous transmission is not required.[13] The ratio is determined by dividing the sum of

[10] This is consistent with the test reductions considered in IEEE 1528 and Supplement C-0101.

[11] Antenna separation is determined by the closest distance between the antennas. (Stand-alone) Routine SAR evaluation is required for licensed transmitters; therefore, this only applies to unlicensed transmitters satisfying the specific P_{Ref} and antenna separation conditions.

[12] This applies to both licensed and unlicensed transmitters that require stand-alone 1-g SAR evaluation. When stand-alone 1-g SAR is not required for a transmitter or antenna; for example, when the antenna is between 2.5 and 5.0 cm from other antennas, its SAR is considered zero in the 1-g SAR summing process to determine simultaneous transmission SAR evaluation requirements.

[13] The ratio (0.32) is rounded down to 0.3 for conservativeness. When stand-alone 1-g SAR is not required for a transmitter or antenna; for example, when the antenna is between 2.5 and 5.0 cm from other antennas, its SAR is

the stand-alone 1-g SAR for each pair of antennas, by the closest peak SAR location separation distance.[14] Antenna pairs with SAR to peak location separation ratios ≥ 0.3 are required to be tested for simultaneous transmission to determine the aggregate 1-g SAR. When required, each transmitter should be tested for simultaneous transmission in the configuration (RF channel, operating mode, antenna position, etc.) that results in the highest SAR during stand-alone evaluation.[15] An overview of the procedures is summarized in Table 2, and is also illustrated by the flow charts in Figure 1 – 4.

5. Other Considerations

Simultaneous Transmission SAR Tests:

When antennas transmit simultaneously in the same frequency band, all antennas operating simultaneously in that frequency range should be evaluated within the same SAR measurement to determine the highest 1-g SAR. This requires a sufficiently large area scan measurement region to enclose all antennas, and search for the SAR peaks. However, if transmit diversity applies to one or more of the antennas, each antenna may have to be evaluated separately according to the test software and SAR procedures required for antenna diversity. For antennas transmitting simultaneously in different frequency bands, different tissue simulating liquids and SAR probe calibrations are required for measurements in each frequency band. The SAR for these antennas must be measured separately using volume scans that may have additional measurement constraints, especially when different measurement resolutions are required as a result of substantially different transmitter frequencies.

In order to assess overlapping SAR distributions for antennas transmitting in different frequency bands, the handset and its antennas must remain in the same test position for all measurements. This ensures the SAR measured at different frequencies can be summed correctly to compute the 1-g aggregate SAR. The same measurement volume must be used to enclose all the simultaneous transmitting antennas in each measurement. The same spatial resolution and grid spacing are also required for the measured points in each measurement to be summed, on identically registered spatial grids to account for the overlapping contributions through post-processing. The volume scan required for simultaneous transmission is equivalent to an oversized zoom scan used in stand-alone measurements. Because of the substantially larger measurement volumes and smaller grid resolutions required for volume scans, these measurements are typically time consuming. While the measurements are complex and often have significant constraints, the procedures in this document should enable grantees to expedite equipment certification by determining in advance the specific conditions necessary to minimize or avoid some of these complex tests.

SAR Tests in Mouth and Jaw Regions of the SAM Phantom:

Antennas located near the bottom of a phone may require SAR measurements around the mouth and jaw regions of the SAM head phantom. This typically applies to clam-shell style phones that are generally longer in the unfolded normal use positions or to certain older style long rectangular phones. It has been known for some time that there are SAR measurement difficulties in these regions of the SAM phantom.[16] SAR probes are calibrated in tissue-equivalent liquids with sufficient separation between the

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considered zero in applying the SAR to peak location separation ratio procedure to determine simultaneous transmission SAR evaluation requirements.

[14] Values for SAR, distance and SAR to peak location separation ratio are rounded to two decimal places in computations.

[15] When stand-alone SAR is not required, test simultaneous transmission on the highest output channel. Contact the FCC laboratory when an antenna is shared by multiple transmitters resulting in multiple maximum stand-alone SAR configurations for the same antenna.

[16] These measurement difficulties are similar to those at the ear that resulted in a wedge shaped ear spacer on the SAM phantom.

probe sensors and nearby physical boundaries to ensure scattering does not affect probe calibration. When the probe tip is moved into tight regions with multiple boundaries surrounding its sensors, probe calibration and measurement accuracy can become questionable. In addition, these measurement locations often require a probe to be tilted at steep angles, where it may no longer comply with calibration requirements and measurement protocols, or satisfy the required measurement uncertainty. In some situations it is not feasible to tilt the probe or rotate the phantom, as suggested by measurement standards, to conduct these measurements.

In order to ensure there is sufficient conservativeness for ensuring compliance until practical solutions are available, additional measurement considerations are necessary to address these technical difficulties. When measurements are required near the mouth, nose, jaw or similar tight regions of the SAM phantom, area or zoom scans are often unable to fully enclose the peak SAR location as required by IEEE 1528 and Supplement C, due to probe orientation and positioning difficulties. Even when limited measurements are possible, the test results could be questionable due to probe calibration and measurement uncertainty issues. Under these circumstances, the following procedures apply. The SAR required in these regions of SAM should be measured using a flat phantom. Rectangular shaped phones should be positioned with its bottom edge positioned from the flat phantom with the same distance provided by the cheek touching position using SAM. The ear reference point (ERP, as defined for SAM) of the phone should be positioned ½ cm from the flat phantom shell.[17] Clam-shell phones should be positioned with the hinge against a smooth edge of the flat phantom where the upper half of the phone is unfolded and extended beyond the phantom side wall. The lower half of the phone is secured in the test device holder at a fixed distance below the flat phantom determined by the minimum separation along the lower edge of the phone in the cheek touching position using SAM.[18] If there is substantial variation in separation distance along the lower edge of a clam-shell phone when placed in the cheek touching position using SAM, the FCC Laboratory may be contacted for additional guidance to position the phone for testing.[19]

The flat phantom data should allow test results to be compared uniformly across measurement systems, until suitable solutions are available in measurement standards to address certain probe calibration and positioning issues, due to implementation differences between horizontal and up-right SAM configurations. These flat phantom procedures are only applicable to stand-alone SAR evaluation in tight regions of the SAM phantom, where measurement is not feasible or test results can be questionable due to probe calibration and accessibility issues. Details on device positioning and photos showing how separation distances are determined should be included in the SAR report. SAR for other regions of the head must be evaluated using SAM; therefore, a phone with antennas at different locations may require flat and SAM phantom evaluation for the different antennas. When simultaneous transmission SAR evaluation is necessary in these regions of SAM and until practical solutions are available, the FCC Laboratory should be contacted for interim guidance.

[17] A spacer should be used to position the phone consistently for all measurements. After a phone is secured in its test device holder with the required spacing, the spacer must be removed before SAR measurement.

[18] Depending on the points of contact on SAM, the position of a phone may not be parallel to the flat phantom.

[19] Clam-shell phones tend to leave an uneven gap between the lower edge of the phone and the curved surfaces near the mouth and jaw regions of SAM.

Table 1 – Output Power Thresholds for Unlicensed Transmitters

	2.45	5.15 - 5.35	5.47 - 5.85	GHz
P_{Ref}	12	6	5	mW
Device output power should be rounded to the nearest mW to compare with values specified in this table.				

Table 2 – Summary of SAR Evaluation Requirements for a Cell Phone with Multiple Transmitters

	Individual Transmitter	Simultaneous Transmission
Licensed Transmitters	Routine evaluation required	SAR not required: Unlicensed only o when stand-alone 1-g SAR is not required and antenna is ≥ 5 cm from other antennas Licensed & Unlicensed o when the sum of the 1-g SAR is < 1.6 W/kg for all simultaneous transmitting antennas o when SAR to peak location separation ratio of simultaneous transmitting antenna pair is < 0.3 SAR required: Licensed & Unlicensed antenna pairs with SAR to peak location separation ratio ≥ 0.3; test is only required for the configuration that results in the highest SAR in stand-alone configuration for each wireless mode and exposure condition Note: simultaneous transmission exposure conditions for head and body can be different for different style phones; therefore, different test requirements may apply
Unlicensed Transmitters	When there is no simultaneous transmission – o output ≤ 60/f: SAR not required o output > 60/f: stand-alone SAR required When there is simultaneous transmission – Stand-alone SAR not required when o output ≤ 2·P_{Ref} and antenna is ≥ 5.0 cm from other antennas o output ≤ P_{Ref} and antenna is ≥ 2.5 cm from other antennas o output ≤ P_{Ref} and antenna is < 2.5 cm from other antennas, each with either output power ≤ P_{Ref} or 1-g SAR < 1.2 W/kg Otherwise stand-alone SAR is required When stand-alone SAR is required o test SAR on highest output channel for each wireless mode and exposure condition o if SAR for highest output channel is > 50% of SAR limit, evaluate all channels according to normal procedures	
Jaw, Mouth and Nose	Flat phantom SAR required o when measurement is required in tight regions of SAM and it is not feasible or the results can be questionable due to probe tilt, calibration, positioning and orientation issues o position rectangular and clam-shell phones according to flat phantom procedures and conduct SAR measurements for these specific locations	When simultaneous transmission SAR testing is required, contact the FCC Laboratory for interim guidance.

Figure 1: Licensed Transmitter SAR Requirements for a Cell Phone

(Flow Chart is for Illustration Only)

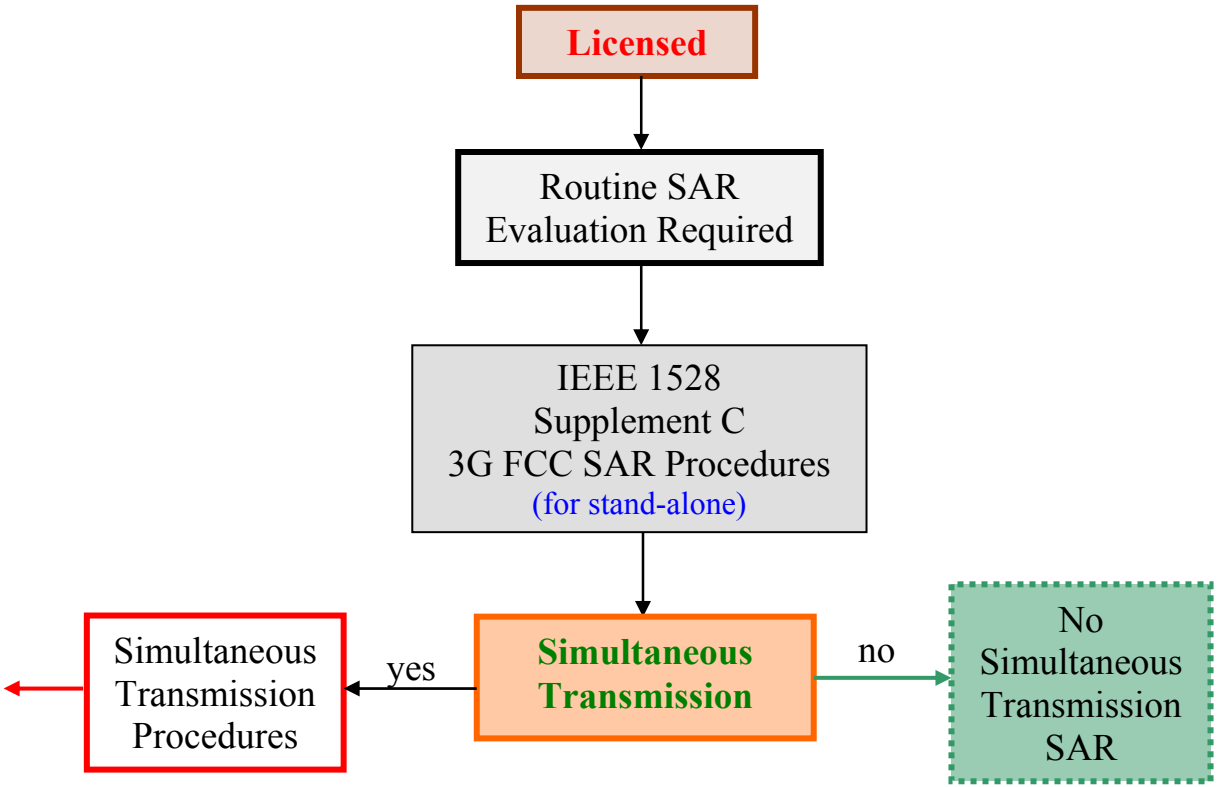
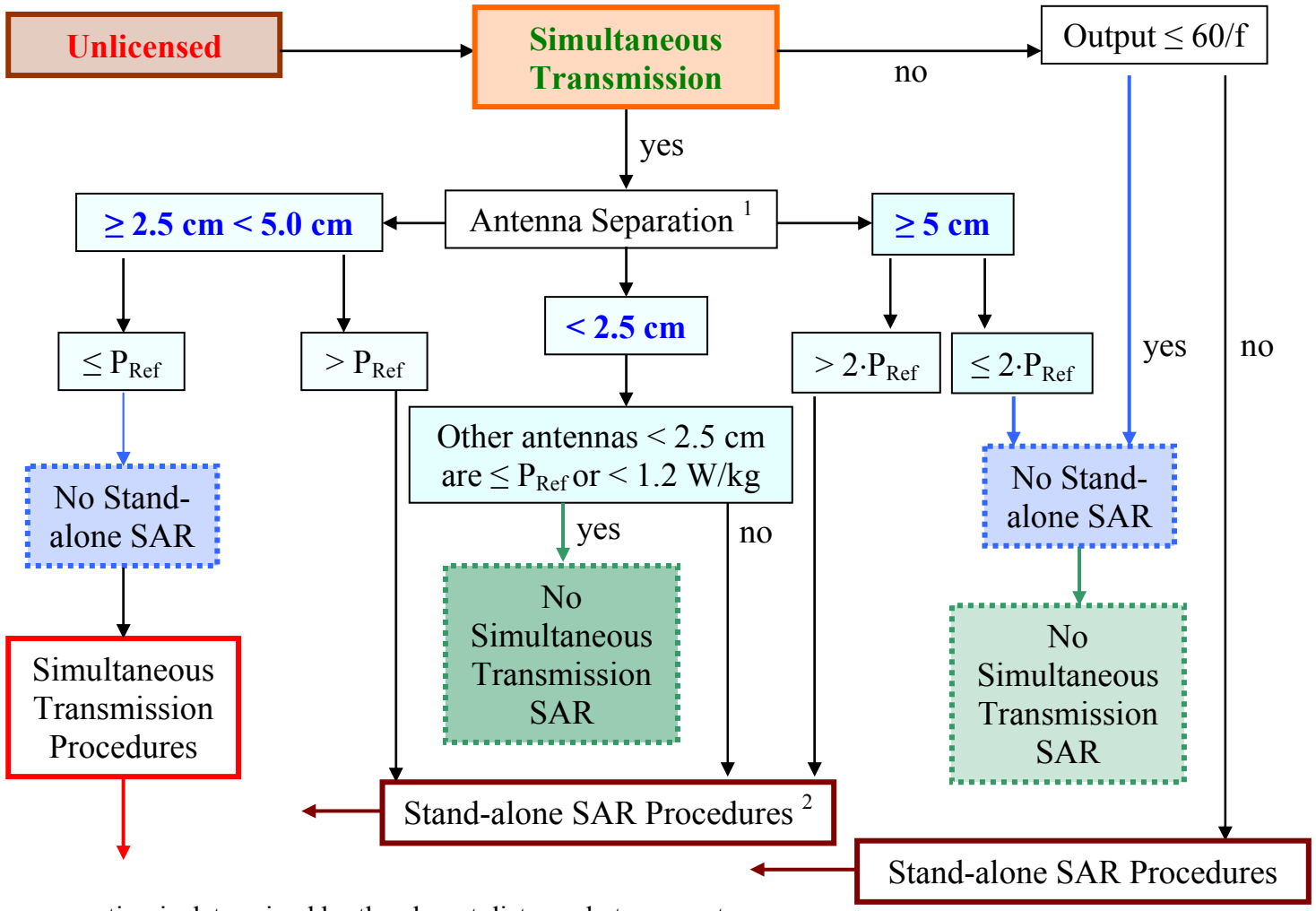


Figure 2: Unlicensed Transmitter SAR Requirements for a Cell Phone

(Flow Chart is for Illustration Only)



[1] Antenna separation is determined by the closest distance between antennas

[2] When simultaneous transmission applies, reduced antenna separations may require SAR at ≤ 60/f

Figure 3: Unlicensed Stand-alone SAR Procedures for a Cell Phone

(Flow Chart is for Illustration Only)

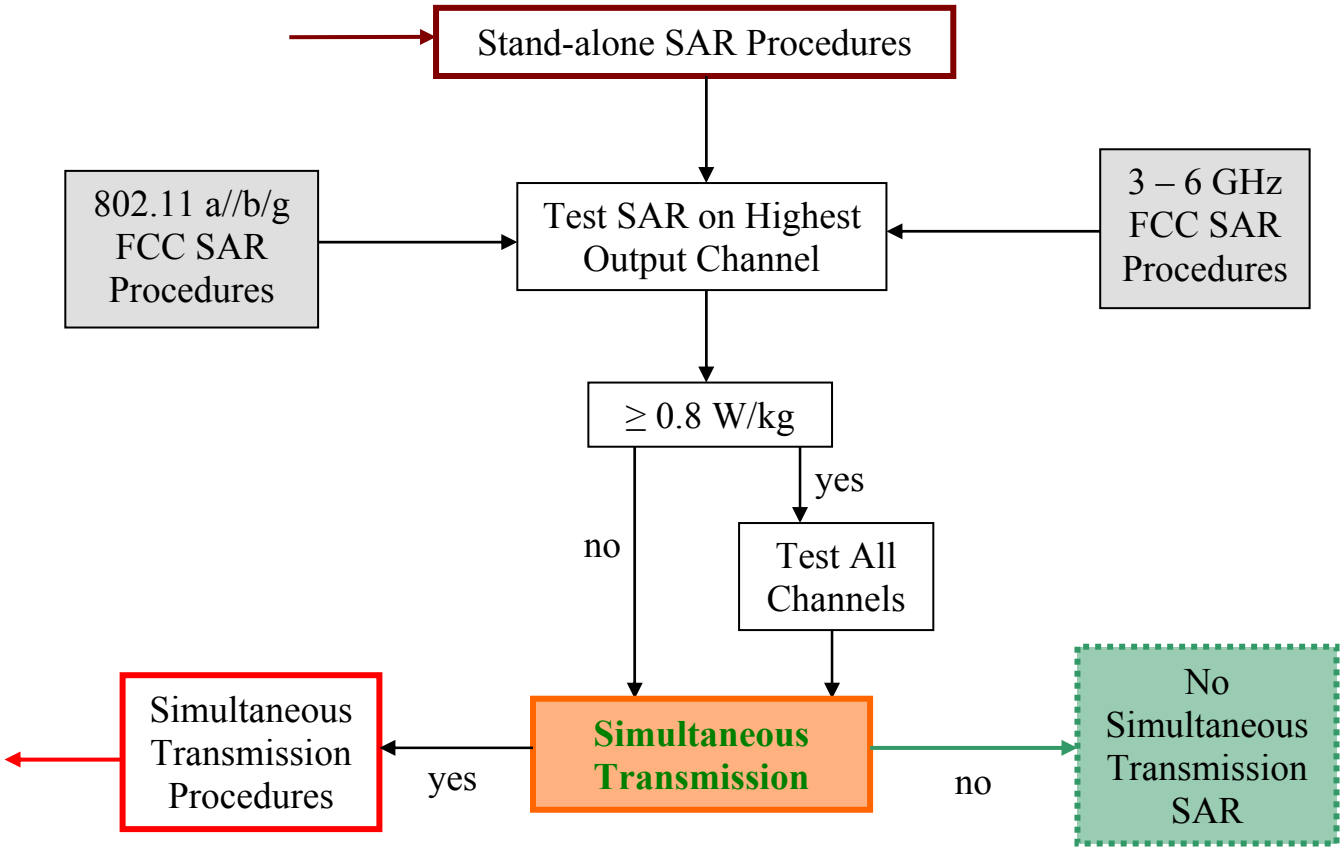
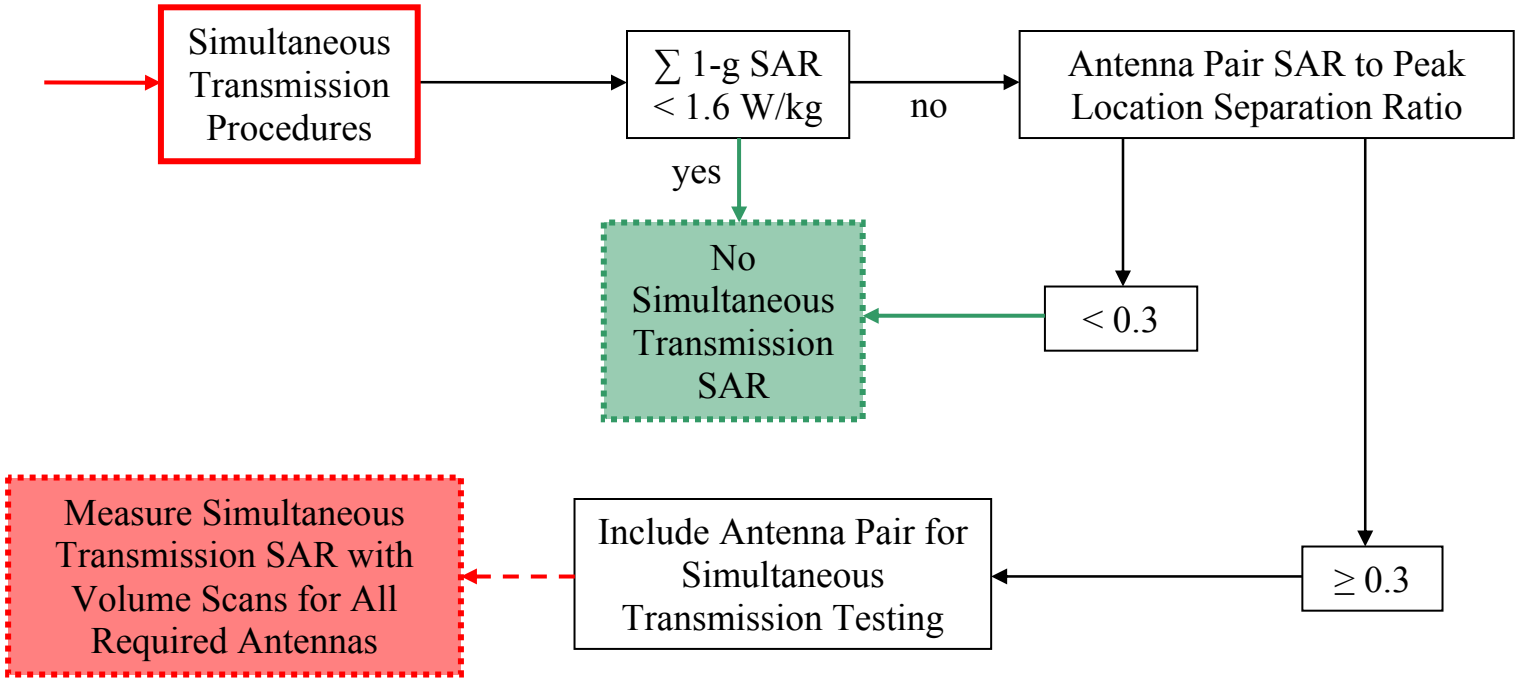


Figure 4: Simultaneous Transmission SAR Procedures for a Cell Phone

(Flow Chart is for Illustration Only)



Note: Simultaneous transmission exposure conditions for head and body can be different for certain style phones; therefore, different test requirements may apply. For example, clam-shell phones in open and folded operating configurations.

Change Notice:

Current Change:

648474 D01 SAR Handsets Multi Xmiter and Ant, v01r05 replaces 648474 D01 SAR Handsets Multi Xmiter and Ant, v01r04:

Footnote 13 has been corrected:

To: "*The ratio (0.32) is rounded down to 0.3 for conservativeness. When stand-alone 1-g SAR is not required for a transmitter or antenna; for example, when the antenna is between 2.5 and 5.0 cm from other antennas, its SAR is considered zero in applying the* ***SAR to peak location separation*** *ratio procedure to determine simultaneous transmission SAR evaluation requirements."*

From: 648474 D01 SAR Handsets Multi Xmiter and Ant, v01r04 - "*The ratio (0.32) is rounded down to 0.3 for conservativeness. When stand-alone 1-g SAR is not required for a transmitter or antenna; for example, when the antenna is between 2.5 and 5.0 cm from other antennas, its SAR is considered zero in applying* ***the SAR-to-antenna*** *ratio procedure to determine simultaneous transmission SAR evaluation requirements."*

Previous Changes:

I. 648474 D01 SAR Handsets Multi Xmiter and Ant, v01r04 replaces 648474 D01 SAR Handsets Multi Xmiter and Ant, v01r03.

This revision has incorporated the following main changes:

1. Footnote 12 and 13 have been revised to clarify that test reduction and exclusion considerations for simultaneous transmission can be applied to unlicensed antennas located between 2.5 and 5 cm from other antennas.
2. Under the subsection Simultaneous Transmission SAR Test Procedures of section 4 – Simultaneous Transmission, SAR to "antenna" separation has been replaced by SAR to "peak location" separation to correct discrepancies between the word "antenna" and the corresponding discussions throughout that section. Figure 4 is also revised to reflect this change.
3. Addition of document control note at the end of the document.